

WÄRTSILÄ
power
PLANTS

FIRMING 3000 MWS OF WYOMING WIND FOR THE CALIFORNIA MARKET

**Presented to Wyoming Infrastructure
Authority Board of Directors**

Cheyenne, WY

May 10, 2011



AGENDA

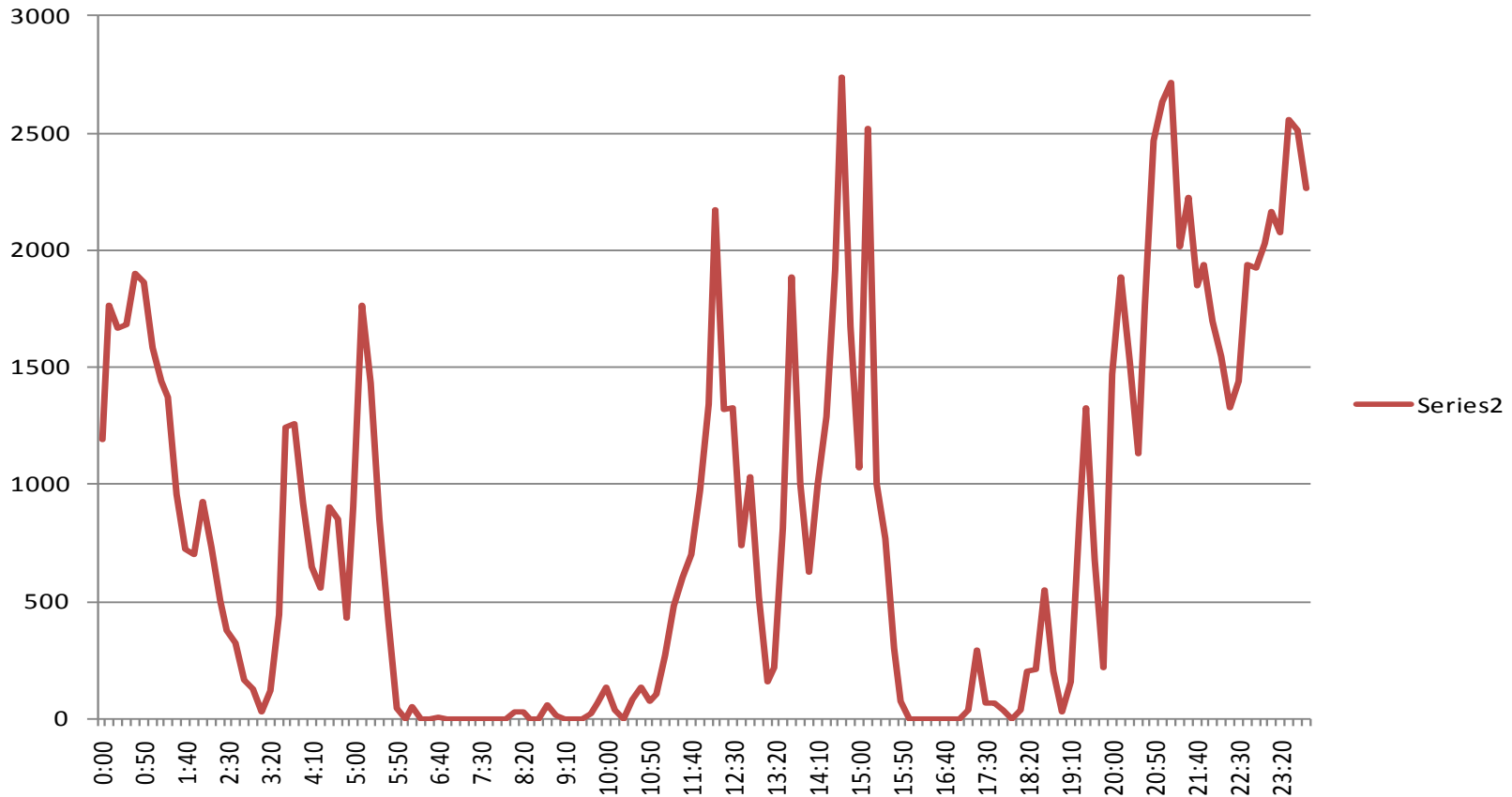
- **Purpose of Presentation and Presentation Basis**
- **Model Inputs for Recip SC, Recip CC, GTSC, GTCC**
- **Model Outputs**
- **Important Technology Requirements**
- **The Winning Technology**

Purpose of Presentation

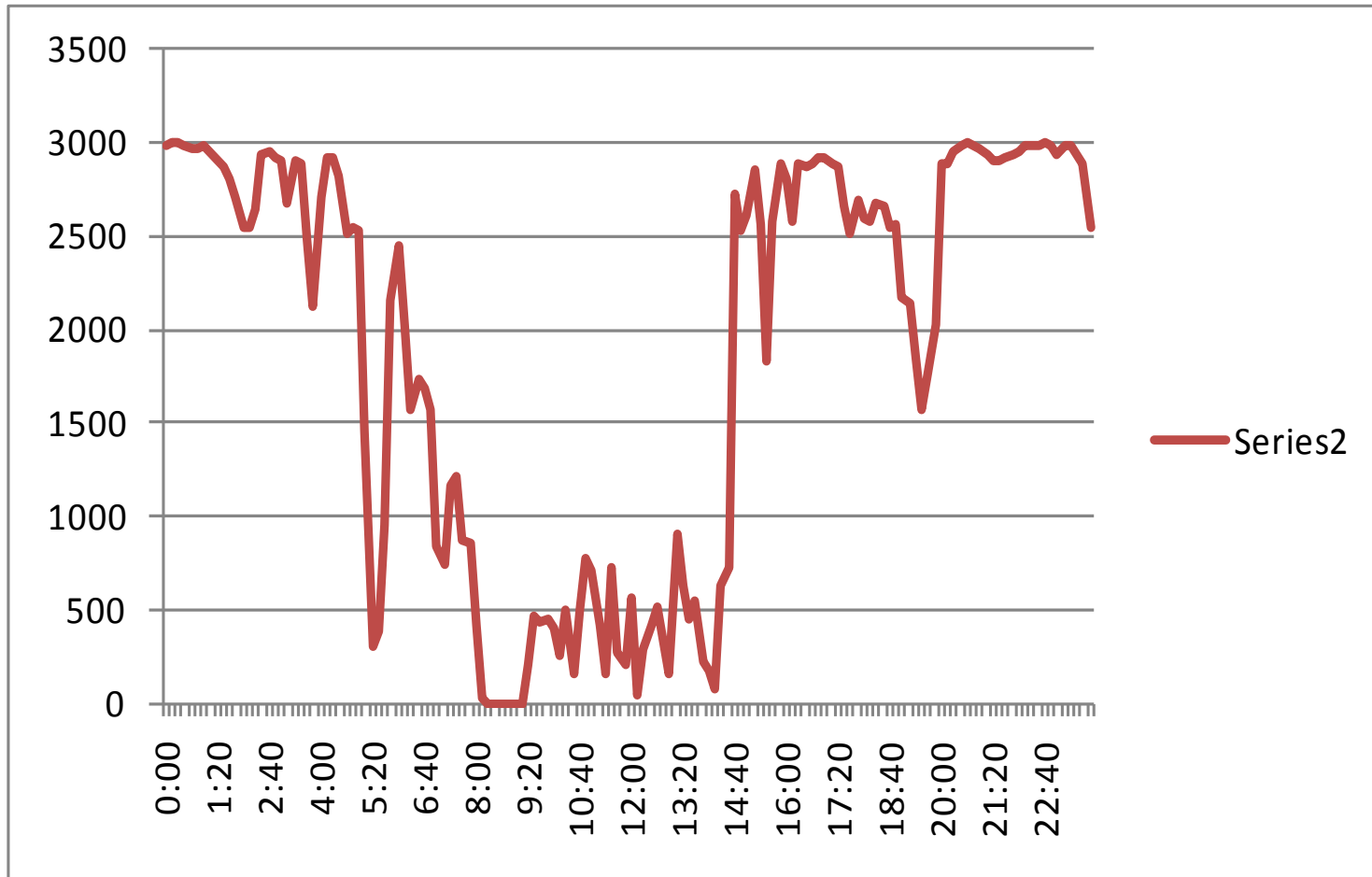
Develop Firming Strategy for 3,000 MWs of Wyoming Power being marketed to the California market via a dedicated transmission line

Why the Fuss? See next three slides!

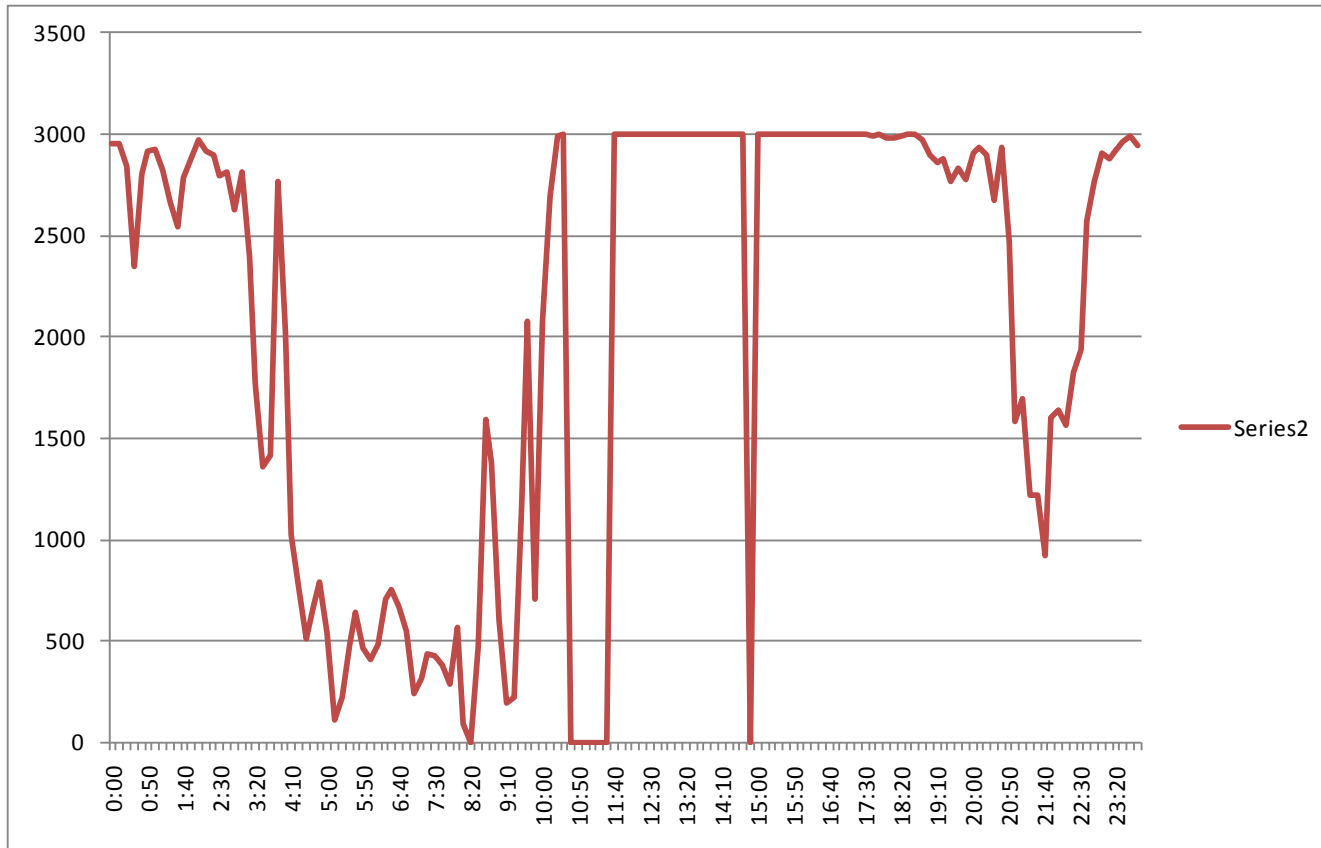
Windfarm "Normal Day" Down Ramp of 1,500 MWs in 10 Minutes



Windfarm 2,000 MW Change in 10 minutes



Windfarm – 3,000 MW Change in 10 Minutes



Basis of Analysis

- **WY Wind data , High Capacity Location, 10 minute intervals**
- **GT performance from GT Probe**
- **Reciprocating Engine performance from Recip Vendor**
- **Inputs shown when discussing Model**
- **Plexos Model used to analyze the system**

ANALYTICAL MODEL USED - PLEXOS

- **PLEXOS for Power Systems[®] is a proven simulation tool that uses cutting-edge data handling and mathematical programming, and stochastic optimization techniques to provide a robust analytical framework for power market analyses.**
- **PLEXOS meets the demands of power market participants and analysts with a comprehensive range of capabilities.**

500 MW Reciprocating Engine Combined Cycle



GT – Simple Cycle

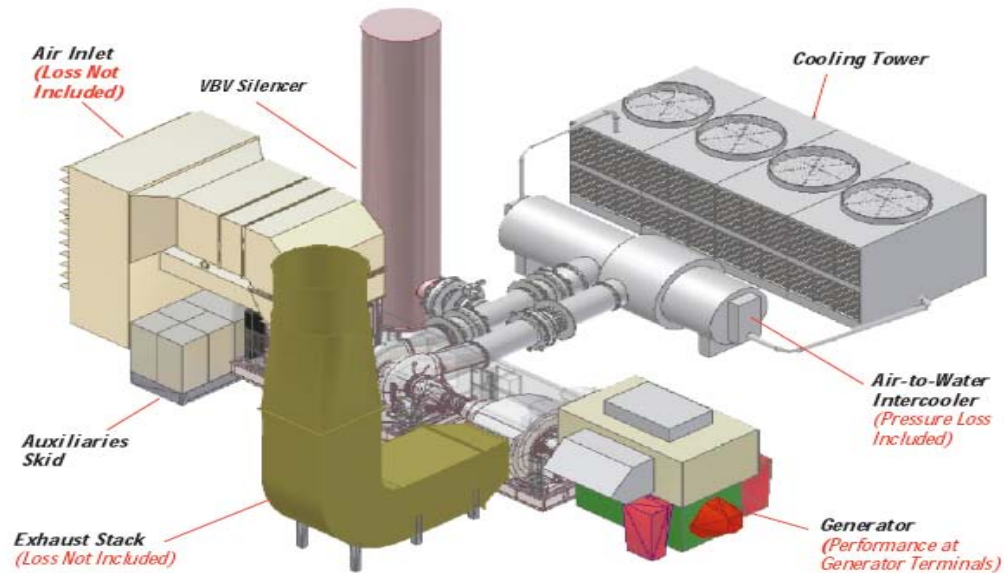
LMS100 ISO Performance Data

Simple Cycle Gas Turbine 50Hz Applications

| Model | Output (MWe) | Heat Rate (KJ/KWH) | Efficiency % |
|---------------|--------------|--------------------|--------------|
| DLE | 99 | 7921 | 45 |
| SAC (w/Water) | 102.5 | 8247 | 44 |
| SAC (w/Steam) | 102.2 | 7603 | 47 |
| STIG | 110.8 | 7263 | 50 |

Conditions:

Performance at the generator terminals
NO_x = 25 ppm
15°C, 60% Relative Humidity
Losses: 0mm/0mm inlet/exhaust
Fuel: Spec Gas (LHV = 44.2MJ/KG)



Simple Cycle Reciprocating Engine Power Plant

- 18 x 18V50SC engines
- 336 MW output
- Natural gas fuel



Goals and Requirements

- **Use absolute minimum amount of NG for firming**
- **Operate NG in conjunction with windfarm to maintain a steady 3,000 MWs to the market**
- **Achieve blended generation cost that meets California Market pricing**

Model Input, Dynamic Features of NG Plants

Dynamic features

| | | | | | |
|---------------------------------------|---------|---|----|----|-----|
| Run up from zero to min stable load | minutes | 5 | 5 | 15 | 30 |
| Ramp up from min stable to max load | minutes | 5 | 5 | 5 | 10 |
| Ramp down from max to min stable load | minutes | 5 | 5 | 5 | 10 |
| Run down from min stable to zero load | minutes | 1 | 1 | 2 | 10 |
| Min Up Time | minutes | 5 | 15 | 30 | 180 |
| Min Down Time | minutes | 5 | 5 | 60 | 120 |

Model Inputs

| Plant type | Required load | Recip SC | Recip CC | GT SC | CCGT |
|--|-----------------|----------------------|----------|----------------------|------|
| Site conditions | | | | | |
| Altitude | feet | 5000 | | | |
| | meter | 1520 | | | |
| Natural gas price | USD/MMBTU (HHV) | 5.0 | | | |
| | USD/MMBTU (LHV) | 5.5 | | | |
| | USD/GJ (LHV) | 5.3 | | | |
| | USD/MWh | 18.9 | | | |
| Natural gas line pressure | bar | 44 | | | |
| Basic Plant data | | | | | |
| Number of units | # | 183 | 175 | 37 | 15 |
| Size of unit | MW / unit | 17 | 18 | 83 | 209 |
| Size of the plant | MW / plant | 3030 | 3066 | 3030 | 3051 |
| Plant efficiency at full load, new and clean | % | 44.4 | 47.1 | 41.7 | 53.3 |
| Average tolerance and aging | % | -1.0 | -1.0 | -3.0 | -3.0 |
| Plant efficiency at full load, life time | % | 44.0 | 46.6 | 40.4 | 51.7 |
| Corresponding heat rate | kJ/kWh | 8190 | 7721 | 8900 | 6963 |
| | Btu/kWh | 7763 | 7318 | 8436 | 6600 |
| Minimum stable load | % | 30 | 30 | 35 | 35 |
| Condense cooling, combined cycle | | Air Cooled Condenser | | Air Cooled Condenser | |
| VOM including consumables | \$/MWh | 6.0 | 6.0 | 5.0 | 4.0 |

Model Input, Investment Cost

Investment costs

| | | | | | |
|-------------------------------|----------------|-------|-------|-------|-------|
| EPC price | USD/kW el | 900 | 950 | 950 | 1050 |
| Interest rate, IDC | % | 10 | 10 | 10 | 10 |
| Construction time | months | 18 | 20 | 18 | 30 |
| IDC factor | - | 0.075 | 0.083 | 0.075 | 0.125 |
| ECP price including IDC | USD/kW el | 968 | 1029 | 1021 | 1181 |
| Interest rate, life time | % | 10 | 10 | 10 | 10 |
| Plant life time | years | 20 | 20 | 20 | 20 |
| Annuity factor | - | 0.117 | 0.117 | 0.117 | 0.117 |
| Annual capital cost | USD/kW el year | 114 | 121 | 120 | 139 |
| Annual fixed cost | USD/kW el year | 10 | 12 | 10 | 12 |
| Annual capital and fixed cost | USD/kW el year | 124 | 133 | 130 | 151 |
| Annual capital cost | Mill USD/yr | 344.3 | 370.6 | 363.4 | 423.4 |
| Annual fixed cost | Mill USD/yr | 30.3 | 36.8 | 30.3 | 36.6 |
| Annual capital and fixed cost | Mill USD/yr | 374.6 | 407.4 | 393.7 | 460.0 |

Model Output, Generating Costs Excluding Starts

| Results first week of April (Plexos) | | Required load | Recip SC | Recip CC | GT SC | CCGT |
|--|-----|---------------|-----------|-----------|-----------|-----------|
| Generating costs excluding starts | | | | | | |
| Generation | MWh | 260,149 | 260,168 | 260,370 | 269,400 | 278,324 |
| Overproduction | MWh | | 19 | 221 | 9,251 | 18,175 |
| Start Fuel Offtake | GJ | | 13,953 | 13,354 | 29,401 | 28,942 |
| Fuel Offtake | GJ | | 2,155,591 | 2,035,093 | 2,490,138 | 2,083,445 |
| Total | GJ | | 2,169,544 | 2,048,447 | 2,519,540 | 2,112,387 |
| | MWh | | 602,651 | 569,013 | 699,872 | 586,774 |
| Efficiency excluding starts | % | | 43.4 | 46.1 | 38.9 | 48.1 |
| Efficiency including starts | % | | 43.2 | 45.8 | 38.5 | 47.4 |
| Plant efficiency at full load, new and clean | % | | 44.4 | 47.1 | 41.7 | 53.3 |
| Plant efficiency at full load, life time | % | | 44.0 | 46.6 | 40.4 | 51.7 |
| Plant efficiency at wind power back-up | % | | 43.2 | 45.8 | 38.5 | 47.4 |
| Efficiency drop from new and clean | % | | 1.2 | 1.3 | 3.2 | 5.9 |

Model Output Generating Costs Including Starts

| | | | | | |
|-----------------------|---------|------------|------------|------------|------------|
| Fuel Cost | USD | 11,424,633 | 10,785,991 | 13,197,734 | 11,042,256 |
| Start Fuel Cost | USD | 73,952 | 70,778 | 155,826 | 153,395 |
| VO&M Cost | USD | 1,561,005 | 1,562,219 | 1,347,000 | 1,391,620 |
| Start & Shutdown Cost | USD | 443,710 | 424,666 | 934,958 | 920,367 |
| <hr/> | | | | | |
| Generation Cost | USD | 13,503,300 | 12,843,653 | 15,635,518 | 13,507,638 |
| | USD/MWh | 51.9 | 49.3 | 58.0 | 48.5 |

Model Output, the bottom line

Generating costs (one week)

| | | | | | |
|------------------------------------|---------|------|------|------|------|
| Variable costs | USD/MWh | 51.9 | 49.3 | 58.0 | 48.5 |
| Fixed costs | USD/MWh | 27.7 | 30.1 | 28.1 | 31.8 |
| Total generating costs | USD/MWh | 79.6 | 79.4 | 86.1 | 80.3 |
| Generation costs for required load | USD/MWh | 79.6 | 79.5 | 89.2 | 85.9 |

Actual efficiency and heat rate (one week)

| | | | | | |
|-------------------------|---------|------|------|------|------|
| Efficiency | % | 43.2 | 45.8 | 38.5 | 47.4 |
| Corresponding heat rate | kJ/kWh | 8339 | 7867 | 9352 | 7590 |
| | Btu/kWh | 7904 | 7457 | 8864 | 7194 |

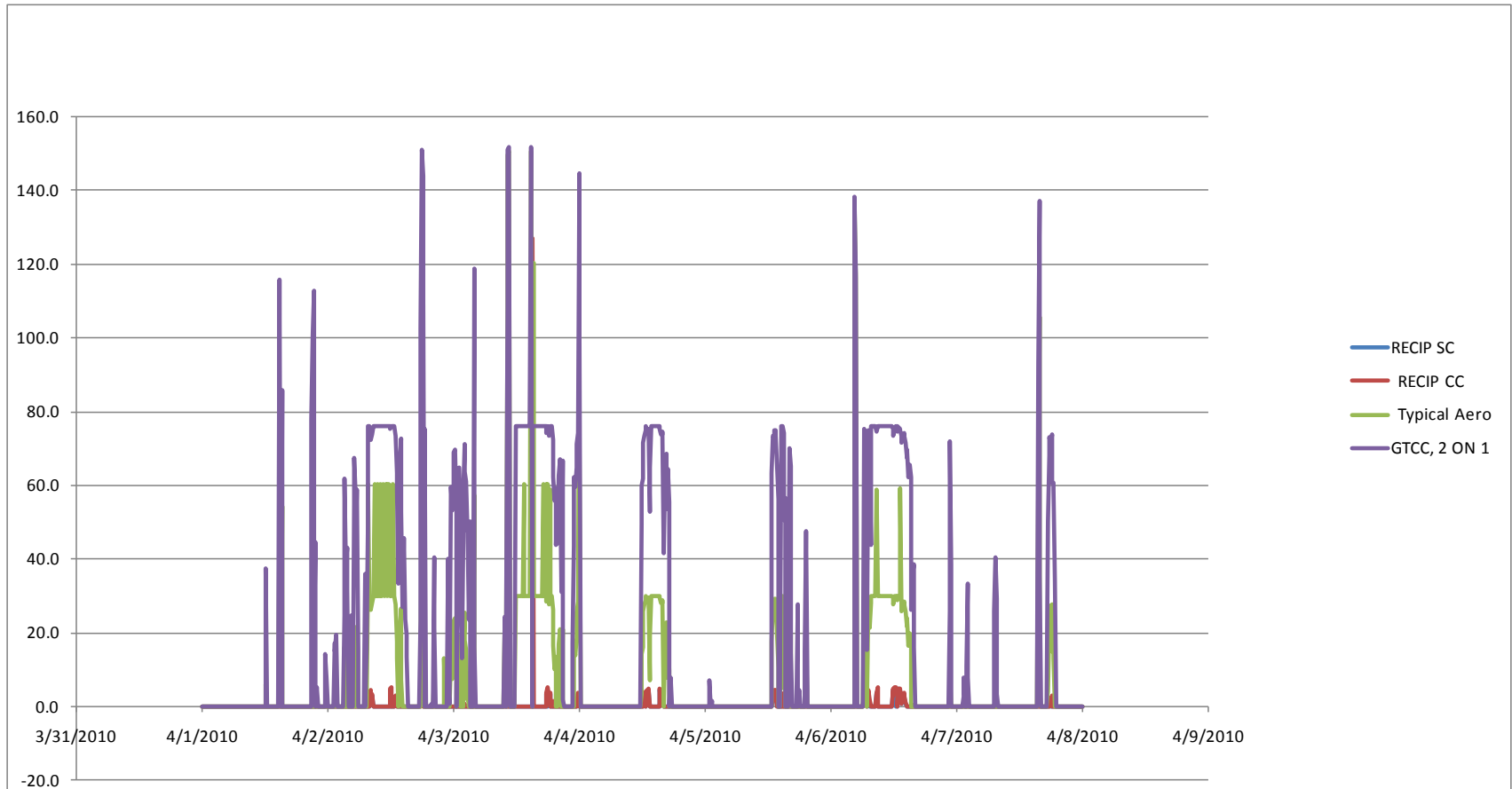
Running hours

| | | | | | |
|----------------------------------|--------------|------|------|------|------|
| Running hours | hours / week | 151 | 151 | 152 | 168 |
| Theoretical annual running hours | hours / year | 7852 | 7852 | 7904 | 8736 |

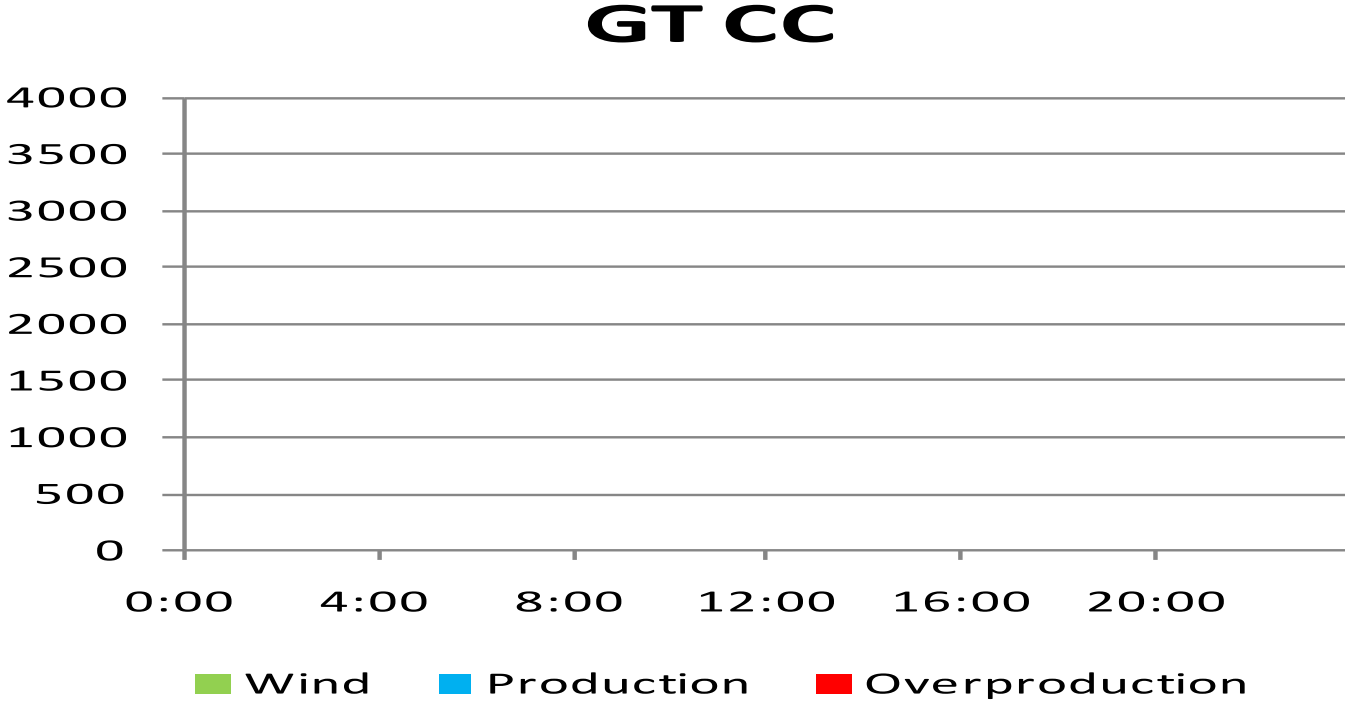
Heat rates

| | | | | |
|---------------------------------|-------|-------|--------|-------|
| Heat rate (Btu/kWh HHV) | 7,996 | 7,594 | 10,312 | 4,235 |
| Blended heat rate (Btu/kWh HHV) | 4,235 | 3,999 | 4,893 | 4,094 |

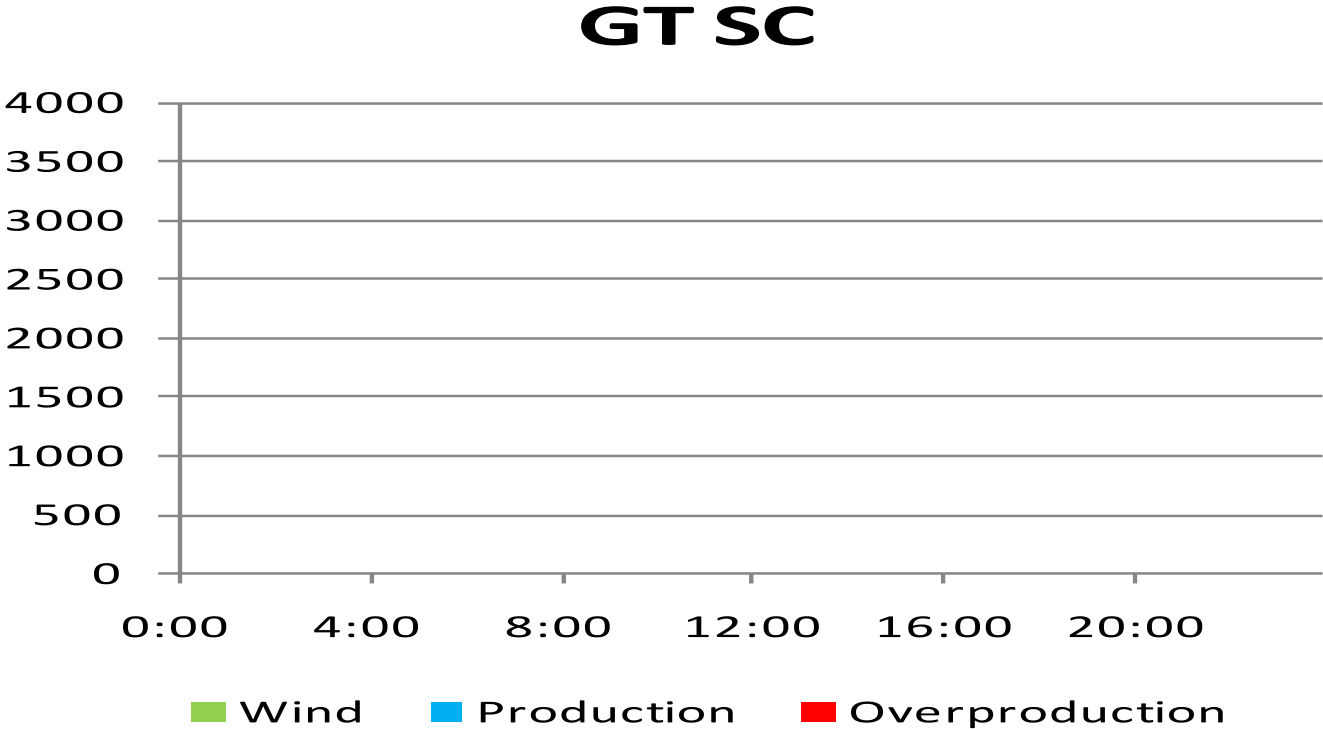
Unnecessary NG Overproduction



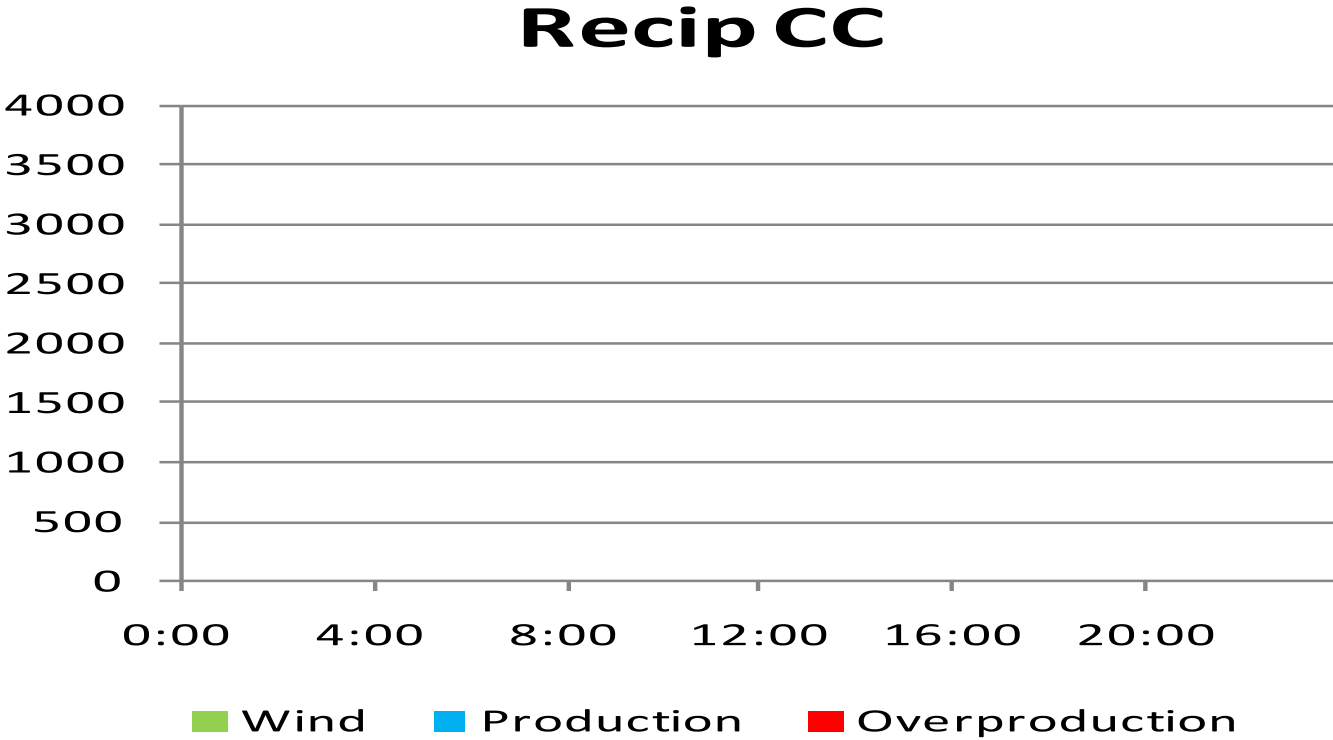
Windfarm plus GTCC Output, showing significant overproduction due to GTCC Loading/Unloading restrictions



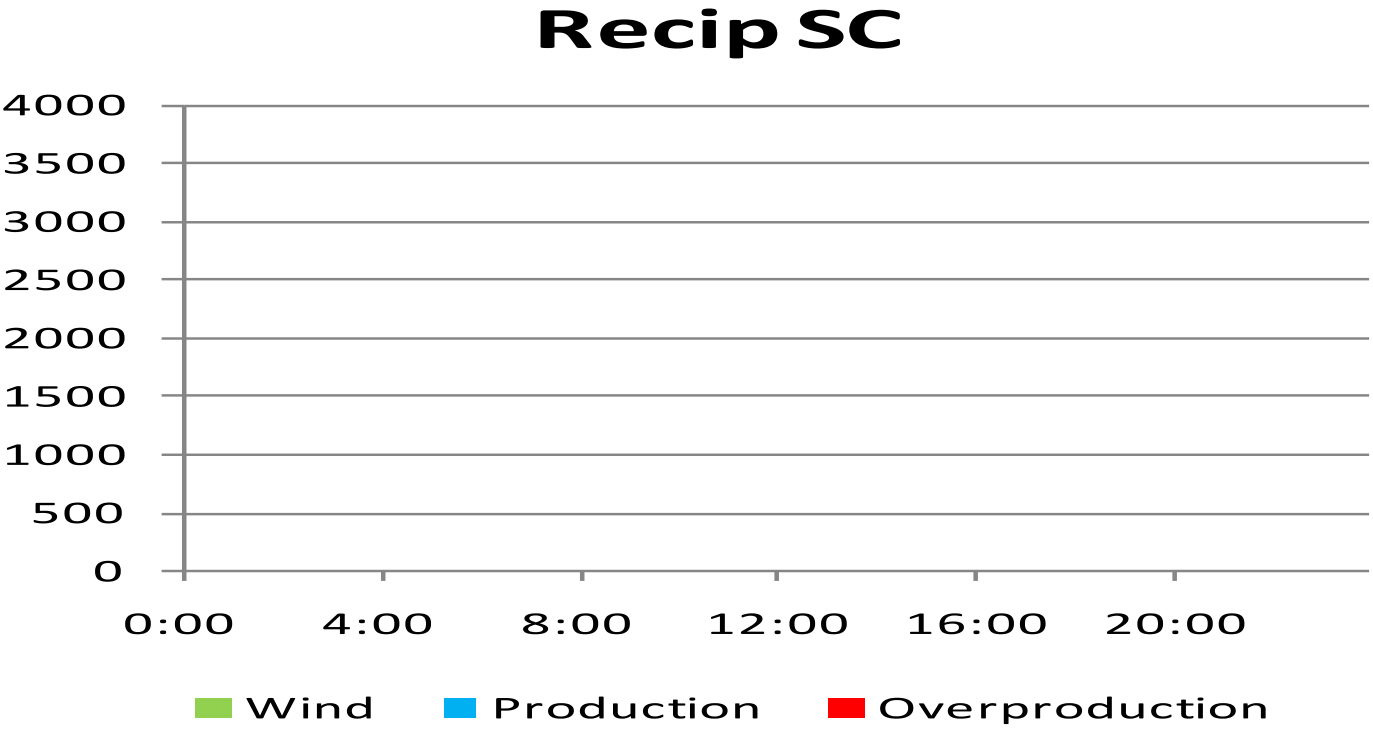
Wind Plus GTSC Output, showing significant overproduction due to Loading/Unloading restrictions of the GTSC



Windfarm plus Recip CC Output, showing minor overproduction due to Loading/Unloading restrictions of the Recip combined cycle



Windfarm plus Recip Simple Cycle production. showing NO overproduction and illustrating the Loading/Unloading capability of the Recip SC





Unlimited starts/stops per day, per year

Low Heat Rate

No starting costs or equivalent running hours

No minimum run time or up time

Full AGC control

Conclusions

- **The wind output CAN be firmed technically to produce a firm 3,000 MW's of generation**
- **That Recip technology provides the best solution - CCGT will not work technically. GTs will overproduce the 3,000 MW line limit by 1,000 MWs**
- **The blended heat rate is feasible for the CA market compared to average pricing**
- **The blended variable cost of generation is feasible for the CA market compared to average pricing**
- **Great variations even the great WY wind - some zero hours**
- **Simple cycle may be best option**

About Wärtsilä

*176 years of
experience*

- \$7.1 billion sales in 2009
- 17,000 employees in 70 countries
- Headquartered in Helsinki, Finland
- 49,000 MWs Land Power + 120,000 MWs Ship Power
- Wärtsilä North America since 1979 (650 employees)

Power PLANTS



Ship power

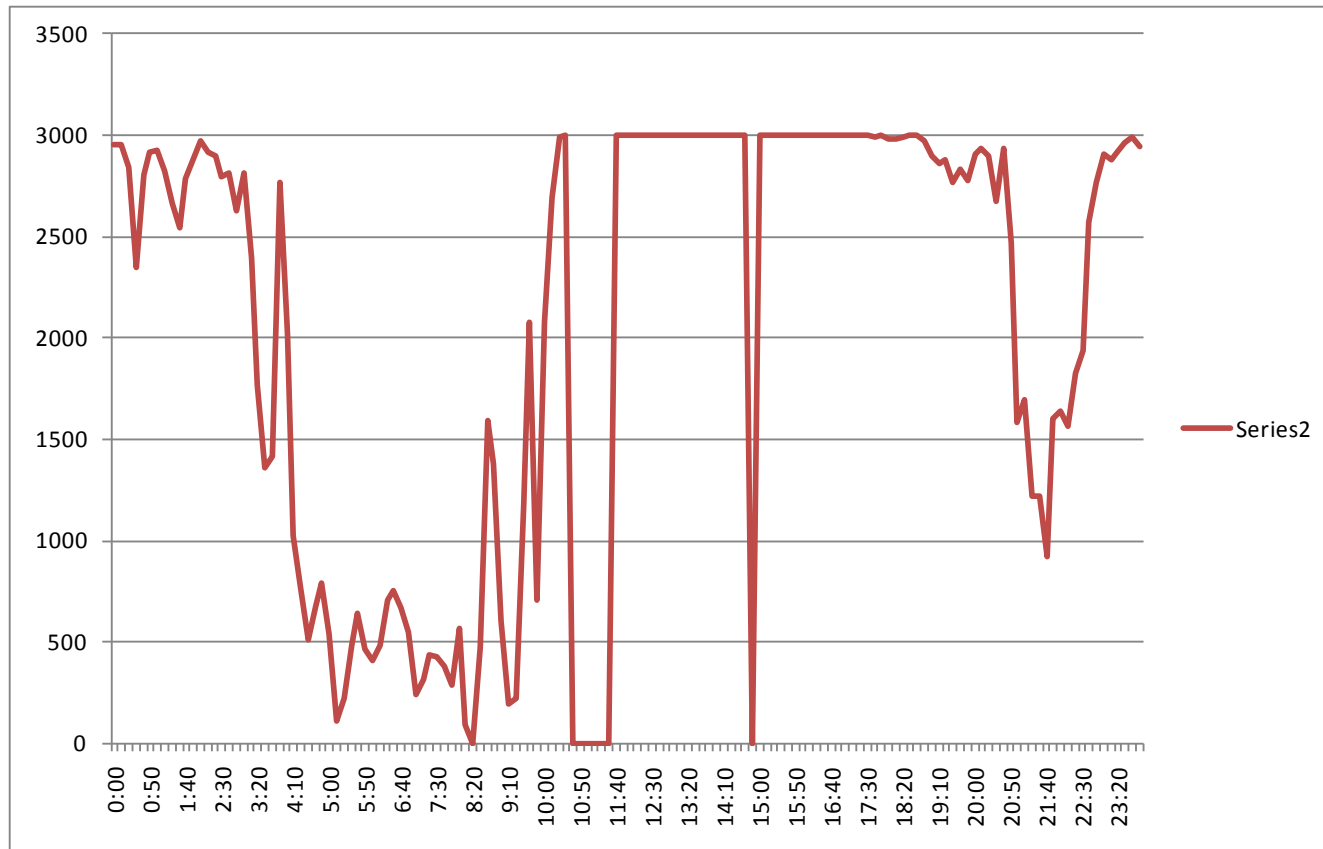


Services



Remember the problem!

Windfarm – 3,000 MW Change in 10 Minutes



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Thank you for your attention

Dennis Finn

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